

Factors Affecting Over Economy of Prefabricated Construction Systems

Motaz Bellah Adel¹ and Prof. Khaled M. Heiza², Prof. Omar El-Nawawy³ and Prof. Ayman Hussein⁴

^{1,3,4} Structural Department, Faculty of Engineering, Ain Shams University
Egypt

² Professor of RC Structures Civil Engineering Department,
Vice Dean, Faculty of Engineering, Menofia University,
Egypt

Abstract

Time in construction is very important parameter effecting in feasibility of project ,that helping in discover a new method take care of time and saving it ,Tilt-up is one of that modern technique which need experience ,The main objective of this study aims to Tilt -up technique which go through some steps begin ,planning ,panelizing, design panels ,finish foundation and floor slab, start casting the panel ,with all inserts needed, begin to Tilt the panel up and fixed it by temporary bracing until all connection and floor slab finish and remove all temporary bracing, these Research has been depended on a questionnaire, the questionnaire Survey was designed based on the objectives of the study and developed to get the opinion from the experienced respondents. Different types of organizations were included, small, medium and big construction companies, consulting offices, general and private companies. The questionnaire distributed to participants to give their experience and opinion.

The factor that economy of prefabricated systems depend on are divided into four groups: Administrative causes, financial causes, Technical causes and General causes.

Quantitative statistical analysis for questionnaire was done by using Statistical tables, The analysis of data is done to rank the severity of factors, Ranking was followed by comparison of mean values within groups and for the overall sub factors as following: ranking of factors for Administrative, ranking of

factors for Financial, ranking of factors for Technical, ranking of factors for General, ranking of Main Groups and Top Ten critical factors, Research has been depended on a case study too, The analysis of data done to get a good view helping in comparison between the tilt-up system and other system, and all analysis done by using engineering economy.

KEYWORDS -Tilt-up, Pre-cast, Net Present Value, Internal Rate of Return, Pay Back period

1. INTRODUCTION

The continuous development in all fields of life , which appear clearly in the industrial field that required more development in construction, to enhance the three parameter of construction management field " time, cost and quality" ,so there is a lot of construction system have been invented , than the traditional one a lot of construction system appear like (Tilt-up),Tilt-up is the technique of site-casting concrete walls or elements, normally on a horizontal surface and then tilting them vertically into place .

Compared to regular concrete construction methods, tilt-up requires a very small amount of formwork. In addition, all wall elements can be cast at once. This makes tilt-up buildings generally faster to build and more economical than cast-in-place buildings.

This research was carried out to study the tilt up system ,its advantage and disadvantage of the system

This research objectives briefly discuss the methodology of tilt up system , and consideration taking in the executing stage , and discuss the economies of the system by two methods first one questionnaire to rank the top ten factor affecting over the economy of prefabricated construction systems in Saudi Arabia by making survey and divided the questionnaire into four groups (administration group ,technical group ,financial group ,general group) , the second method by a taking a case study from project study as precast and it will study as a tilt up system to determine the economy of the system by indicate the rate of return of system with point of view of contractor , even make a value engineer analysis to appear the value of the system at the long term and appear at the same time the cost that saved with keep the function of facility and keep the architecture pattern , make a comparison between the different type of construction system and the tilt up system to determine the effective of tilt up system compared by the other systems.

Significance of the study

saving time in construction field even in an ordinary project, so it need an ordinary tilt-up will save time with suitable mass production ,even with high initial costs tilt-up , so it is good solution for building with big mass production and an ordinary conditions .

The Research Objectives

- 1) To understand the process of precast and tilt-up methods of construction in all shape of projects.
- 2) To identify the factors influencing the economy of prefabricated construction system in Saudi Arabia.
- 3) To analyses the economy of prefabricated concrete construction in Saudi Arabia.

2. LITERATURE REVIEW

From a review of available recent research papers, Last Studies and published materials, there is a procedure summaries tilt-up construction sequence:

- 1) Foundations are placed in its place
- 2) Cast the floor slab

- 3) Walls are cast either on-site using the floor slab as a casting bed A crane is used to lift the panels in place
- 4) Water, power, gas and electrical services need to be cast in to walls
- 5) Brace temporarily the panel in its final place
- 6) The roof can be constructed in the same manner as any other construction method.

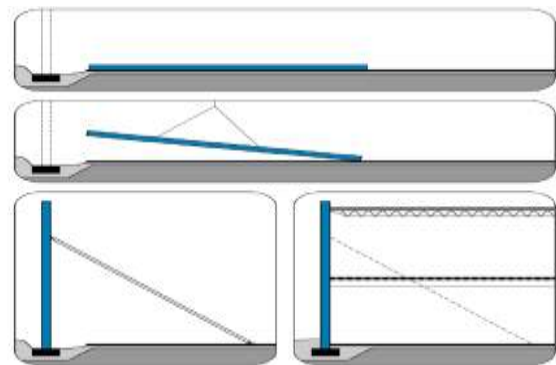


Fig.1 Tilt-Up Construction Sequence

3. REASEARCH METHODOLOGY

At first questionnaire had been made, this questionnaire is an opinion survey administered to contracting companies in Saudi Arabia , This investigation was undertaken in two stages. The first stage ,Was the collection of data, this stage included reviewing related literatures ,and gathering data through site visits, interviews, and discussions with different grade of companies, the second stage focused on data analysis and identification of the most relevant factors influencing causes of failures. This led to the formation of the questionnaire, which was distributed to companies.

Respondents in Survey were asked to rate each factor using a Likert’s scale of 5 ordinal measures from 1 to 5 according to level of contributing. Where :(1) = Strongly Disagree ,(2) = Disagree ,

(3) = Moderate, (4) = Agree, (5) = Strongly Agree

Sample Size Formulas:

A statistical calculation is used to insure that the chosen sample fully represents the population. The formula shown below was used to determine the sample size of unlimited population.

$$SS = \frac{Z^2 * P * (1 - P)}{C^2} \dots\dots\dots \text{eq(1)}$$

Where: SS = sample size

Z = Z value (e.g. 1.96 for 95% confidence level)
 p = percentage picking a choice, expressed as decimal (0.5 used for sample size needed)
 c = confidence interval, expressed as decimal (e.g. 0.05 = ±5 or 0.10=±10)
 - Sample Size Calculator:

$$SS = \frac{1.96^2 * 0.5 * (1 - 0.5)}{0.10^2} = 96$$

Quantitative statistical analysis for questionnaire was done by using statically tables. The respondents were asked to evaluate the importance level of the factors, Tables below show the ranking of the factors according to their effects as perceived by the respondents.

Table (1): Ranking of Factors for Administrative

ID	Factors	Group	Mean	%	R	Rank on Group
I1	lack of experience in administrate the precast construction system	Administrative factors	3.7	70.2	8	1
I2	weakness databases for previous projects construct with precast construction system	Administrative factors	3.61	71.8	14	2
I4	individual in the decision to work the prefabricated construction system	Administrative factors	3.55	71.2	18	3
I6	lack of information about the volume of work when using the pre-fabricated construction system	Administrative factors	3.53	73.1	19	4
I3	Lack of harmony among the members of the project team	Administrative factors	3.42	76.3	23	5
I5	Lack of powers to control the precast construction system by the project managers.	Administrative factors	3.31	75.9	26	6

Table (2): Ranking of Factors for Financial

ID	Factors	Group	Mean	%	R	Rank on Group
II5	study the project during the tender stage as prefabricated construction system	financial factors	3.87	71	4	1
III1	Increase transportation costs, continuously	financial factors	3.76	75.1	7	2
II3	The high cost of installation due to the use of (cranes)	financial factors	3.65	77.3	11	3
II4	high cash flow due to the short term	financial factors	3.62	71.2	13	4
II2	initial cost of prefabricated construction system	financial factors	3.51	69	21	5

Table (3): Ranking of Factors for Technical

ID	Factors	Group	mean	%	R	Rank on Group
III4	work without following risk management plan.	Technical factors	4	74.1	1	1
III1	Lack of technical experience of employees of the project with prefabricated construction system.	Technical factors	3.89	68.4	3	2
III12	absence of technical skilled trained labor	Technical factors	3.82	66.1	5	3
III6	poor study of site conditions, methods of loading and access and exit places of cranes.	Technical factors	3.67	72.4	10	4
III8	Lack of planning and weakness of consolidation of the track movement of cranes.	Technical factors	3.65	77.8	12	5
III3	work without following good quality control plan.	Technical factors	3.59	80	15	6
III2	A lack of planning for the system activities sequence	Technical factors	3.56	68.4	16	7
III7	Periodic maintenance work.	Technical factors	3.56	73.5	17	8
III9	long distance between the plant and the installation places.	Technical factors	3.53	70.6	20	9
III10	poor design which care of element dimension and weight economically and number of reputation of panel.	Technical factors	3.45	65.9	22	10
III5	The absence of daily follow-up of the implementation on site.	Technical factors	3.42	73.3	24	11
III11	The possibility of re-installation the building in other place without damage.	Technical factors	3.3	67.6	27	12

Table (4): Ranking of Factors for General

ID	Factors	Group	mean	%	R	Rank on Group
IV2	The limited number of subcontractors who specialize in pre-fabricated systems compared to traditional systems	general factors	3.98	72.2	2	1
IV3	The impact of the delay in financing of the project by owner.	general factors	3.8	70.6	6	2
IV1	Increasing in prices of construction materials.	general factors	3.68	73.1	9	3
IV4	Non-availability of a technical solutions to use (prefabricated) in all types of properties in the vertical extract as using in horizontal extract	general factors	3.38	79.6	25	4

Table (5): Ranking and Average Rating of Main Groups

ID	Main Group	Mean	%	R
IV	General factors	3.71	74.18	1
II	financial factors	3.68	73.63	2
III	Technical factors	3.62	72.4	3
I	Administrative factors	3.52	70.41	4

Table (6): Top Ten Critical Factors

ID	Factors	Group	mean	%	R
III4	Work without following risk management plan.	Technical factors	4	74.1	1
IV2	The limited number of subcontractors who specialize in pre-fabricated systems compared to traditional systems	general factors	3.98	72.2	2
III1	Lack of technical experience of employees of the project with prefabricated construction system.	Technical factors	3.89	68.4	3
II5	study the project during the tender stage as prefabricated construction system	financial factors	3.87	71	4
III12	absence of technical skilled trained labor	Technical factors	3.82	66.1	5
IV3	The impact of the delay in financing of the project by owner.	general factors	3.8	70.6	6
II1	Increase transportation costs, continuously	financial factors	3.76	75.1	7
I1	lack of experience in administrate the prefabricated construction systems	Administrative factors	3.7	70.2	8
IV1	Increasing in prices of construction materials.	general factors	3.68	73.1	9
III6	Poor study of site conditions, methods of loading and access and exit places of cranes.	Technical factors	3.67	72.4	10

Secoundly In this study will study a practical project begin to construct by conventional method of construction but due to the bad condition that belongs to the project place and bad weather.

It changing to the precast system to minimize the time of construction, and finally study to construct the same project but with tilt –up and clarify the effect of that changing into the economy of the project from the contractor point view and study how it will effect on reduction in the cost and time and the interest rate of money saved or used the

system as a value engineering tools for the same project with all its conditions.

It is border port between kingdom of Saudi Arabia and Oman, it is divided into two areas one for the customs administration, and the other part is for the residential city, the residential city content from multiphase of housing “168 family villas, 15 building of family apartment, 15 building of bachelor’s apartment In this study the focus will be on the a sample of the family villas and make a model of construct it by the system of tilt up system.

The research study to apply three systems, cast in situ, pre-cast and Tilt-up on the project conditions and compare to select the best economical method to finish project with that all tough

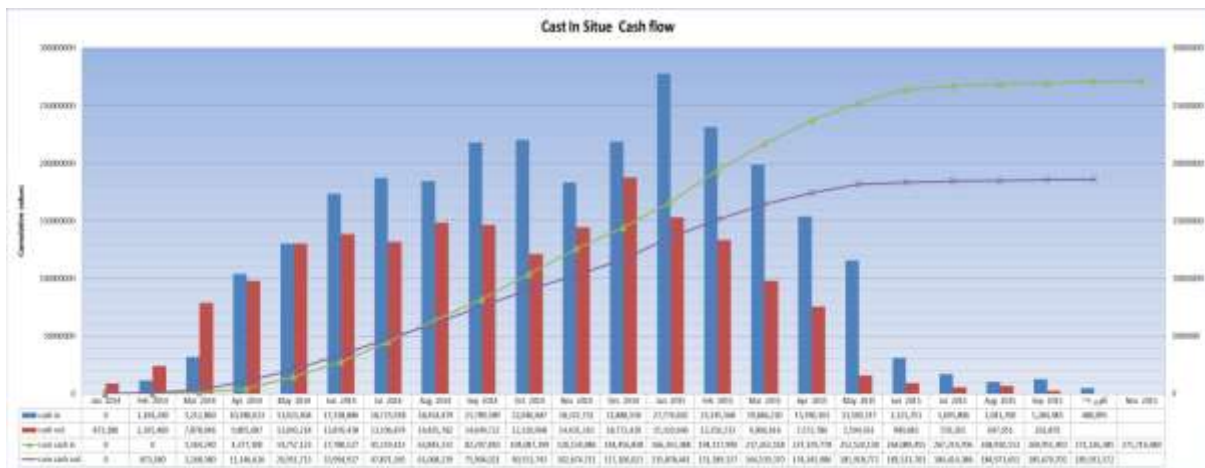
conditions, so after finish the time line of project the cash flow for the three system are as follow.

First the distribution of cash flow of cast in situ:

Table(7)Cast In Situ Cash Flow Table Monthly And Cumulative

Cast in situe cash flow											
	Jan 2014	Feb 2014	Mar 2014	Apr 2014	May 2014	Jun 2014	Jul 2014	Aug 2014	Sep 2014	Oct 2014	Nov 2014
cash In	0	1,164,240	3,212,860	10,380,023	13,023,404	17,338,886	18,723,918	18,454,479	21,789,589	22,046,687	18,322,752
Cash Out	873,180	2,395,400	7,878,046	9,805,087	13,043,214	13,876,438	13,196,874	14,835,782	14,649,722	12,120,968	14,431,310
Cash Flow	-873180	-1231160	-4665186.15	574935.89	-19809.64	3462447.7	5527043.82	3618697.61	7139866.98	9925719.63	3891441.19

	Dec 2014	Jan 2015	Feb 2015	Mar 2015	Apr 2015	May 2015	Jun 2015	Jul 2015	Aug 2015	Sep 2015	42278
cash In	21,886,550	27,774,602	23,145,568	19,866,220	15,390,361	11,569,317	3,125,251	1,695,806	1,041,390	1,284,483	480,095
Cash Out	18,772,420	15,310,696	13,350,233	9,806,616	7,572,786	1,594,931	900,683	559,265	697,051	261,870	0
Cash Flow	3114129.95	12463906.39	9795334.84	10059603.76	7817574.28	9974386.12	2224568.12	1136541.25	344338.75	1022612.5	480095



Fig(2) : Cast In Situ Cash Flow Chart Monthly And Cumulative

Table(8) :Second the cash flow distribution for pre-cast system

Precast cash in												
	Jan 2014	Feb 2014	Mar 2014	Apr 2014	May 2014	Jun 2014	Jul 2014	Aug 2014	Sep 2014	Oct 2014	Nov 2014	Dec2014
mon	0	1,712,760	4,342,997	12,313,811	28,777,690	38,385,937	37,878,437	25,731,010	28,949,434	27,055,258	21,900,958	20,355,008
sum	0	0	1,712,760	6,055,757	18,369,567	47,147,257	85,533,194	123,411,630	149,142,641	178,092,075	205,147,332	227,048,291

Precast Cash Out												
	Jan 2014	Feb 2014	Mar 2014	Apr 2014	May 2014	Jun 2014	Jul 2014	Aug 2014	Sep 2014	Oct 2014	Nov 2014	
mon	1,284,570	3,240,269	9,262,856	19,839,576	20,125,690	19,749,440	12,650,281	13,012,131	11,626,827	9,349,255	5,432,347	
sum	0	1,284,570	4,524,839	13,787,695	33,627,271	53,752,961	73,502,401	86,152,682	99,164,814	110,791,641	120,140,896	125,573,243

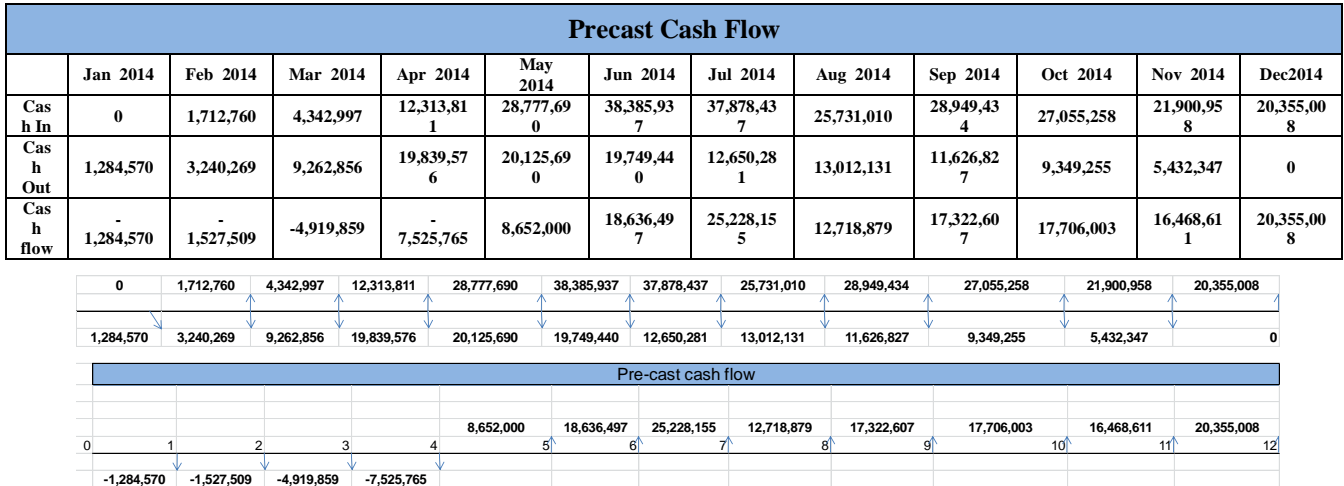
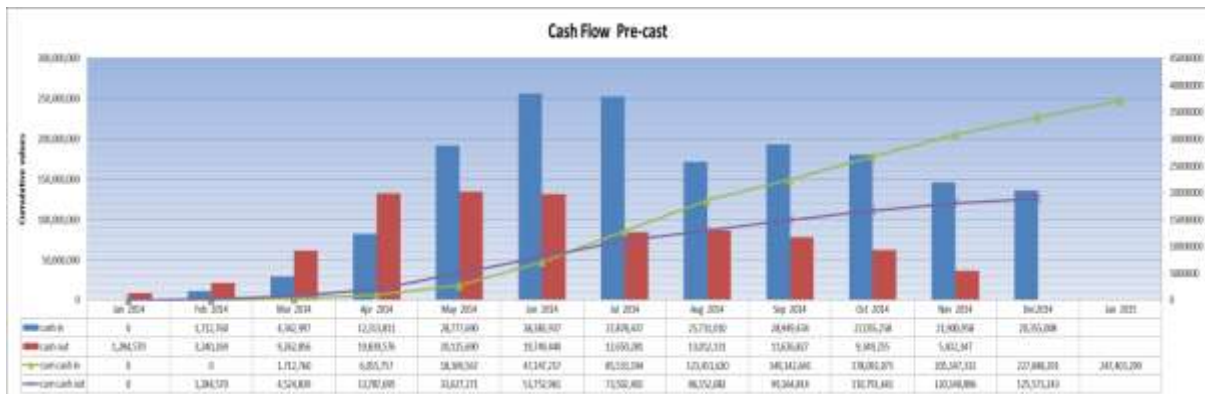


Fig (3) :Pre-Cast Cash Flow Monthly And Cumulative



Fig(4) : Pre-Cast Cash Flow Chart Monthly And Cumulative

Table(9) :Finally the tilt-up cash flow as follow

Tilt-up cash In												
	Jan 2014	Feb 2014	Mar 2014	Apr 2014	May 2014	Jun 2014	Jul 2014	Aug 2014	Sep 2014	Oct 2014	Nov 2014	Dec2014
mon	0	1,712,760	4,342,997	12,313,811	29,808,323	38,385,937	37,878,437	25,731,010	28,949,434	27,055,258	21,900,958	19,324,375
sum	0	0	1,712,760	6,055,757	18,369,567	48,177,890	86,563,827	124,442,264	150,173,274	179,122,708	206,177,966	228,078,924

Tilt-up Cash out												
	Jan 2014	Feb 2014	Mar 2014	Apr 2014	May 2014	Jun 2014	Jul 2014	Aug 2014	Sep 2014	Oct 2014	Nov 2014	
mon	1,284,570	3,240,269	9,262,856	17,649,519	18,257,157	17,880,907	11,212,948	11,143,598	9,758,294	7,822,088	5,125,037	112,637,243
sum	0	1,284,570	4,524,839	13,787,695	31,437,215	49,694,371	67,575,278	78,788,226	89,931,824	99,690,118	107,512,206	112,637,243

Tilt-up cash Flow

	Jan 2014	Feb 2014	Mar 2014	Apr 2014	May 2014	Jun 2014	Jul 2014	Aug 2014	Sep 2014	Oct 2014	Nov 2014	Dec2014
cash In	0	1,712,760	4,342,997	12,313,811	29,808,323	38,385,937	37,878,437	25,731,010	28,949,434	27,055,258	21,900,958	19,324,375
Cash out	1,284,570	3,240,269	9,262,856	17,649,519	18,257,157	17,880,907	11,212,948	11,143,598	9,758,294	7,822,088	5,125,037	0
cash flow	-1284570	-1527509.33	-4919859.38	-5335708.75	11551166.7	20505030.04	26665488.69	14587412.25	19191139.96	19233169.41	16775921.16	19324375

0	1,712,760	4,342,997	12,313,811	29,808,323	38,385,937	37,878,437	25,731,010	28,949,434	27,055,258	21,900,958	19,324,375
1,284,570	3,240,269	9,262,856	17,649,519	18,257,157	17,880,907	11,212,948	11,143,598	9,758,294	7,822,088	5,125,037	0

Tilt-up cash Flow												
0					11,551,167	20,505,030	26,665,489	14,587,412	19,191,140	19,233,169	16,775,921	19,324,375
	-1,284,570	-1,527,509	-4,919,859	-5,335,709								

Fig (5) :tilt-up Cash Flow Monthly And Cumulative



Fig(6) :Tilt-Up Cash Flow Chart Monthly And Cumulative

4. Analysis of cash flows by engineering economy :

Net Present Value(NPV)

$$P = F * (1 + i)^{-n} \dots\dots\dots eq(2)$$

where : P is the present value of money at start of the project

F is the future value of money at the time where it will have action on it

i is the interest rate

n is number of unit of duration like number of years or months after represent the cash

flow as follow

Table (10): NPV of Tilt-up

Month	Cash flow	NPV
0	0	0
1	-1,284,570	-1,265,200
2	-1,527,509	-1,481,791
3	-4,919,859	-4,700,644
4	-5,335,709	-5,021,094
5	11,551,167	10,706,158
6	20,505,030	18,718,446
7	26,665,489	23,975,103
8	14,587,412	12,917,866
9	19,191,140	16,738,435
10	19,233,169	16,522,147
11	16,775,921	14,193,960
12	19,324,375	16,103,646
Net present value		117,407,030
IRR		69%

Interest: 20% monthly rate: 1.53%

Table(11) :NPV of Pre-cast

Month	Cash Flow	NPV
0	0	0
1	-1,284,570	-1,265,200
2	-1,527,509	-1,481,791
3	-4,919,859	-4,700,644
4	-7,525,765	-7,082,016
5	8,652,000	8,019,076
6	18,636,497	17,012,716
7	25,228,155	22,682,788
8	12,718,879	11,263,188
9	17,322,607	15,108,707
10	17,706,003	15,210,243
11	16,468,611	13,933,947
12	20,355,008	16,962,507
Net present value		105,663,521
		105,663,521
IRR		60%

Interest: 20% monthly rate: 1.53%
 The tilt up is the highest value even the initial cost of tilt up is more higher than of cast in situ, but the time value of money give the real view for the investment, precast concrete is in the middle to be the second chance to invest or as good value engineer tools to keep the function but at the same time decrease the cost.

Internal Rate Of Return (IRR)

It is applied by the same equation of (NPV) .

$$ir = i1 + PV(i2-i1) / (pv +Nv) \dots\dots\dots$$

where : **ir** is the internal rate of return

i1 is the discount rate of positive NPV

i2 is the discount rate of positive NPV

pv is the positive value of NPV

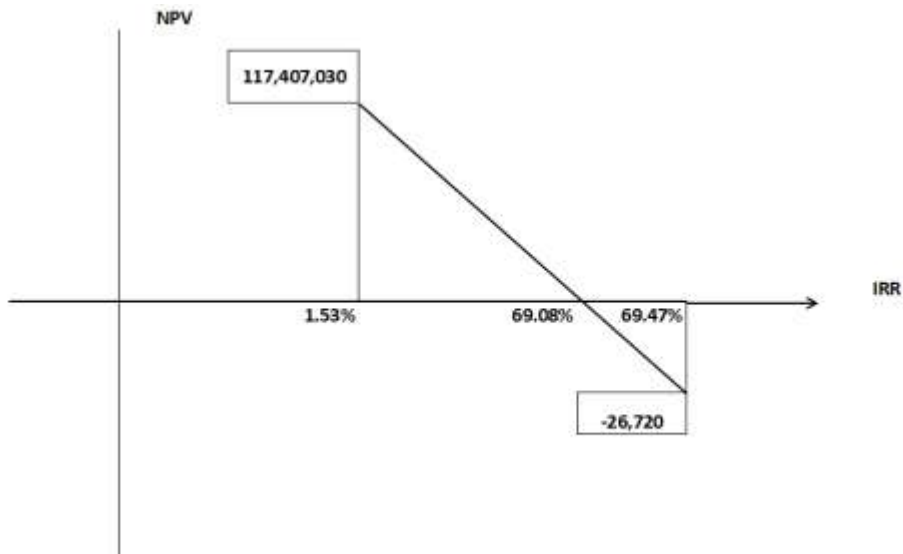
Nv is the negative value of NPV

And by represent the equation graphically it will be

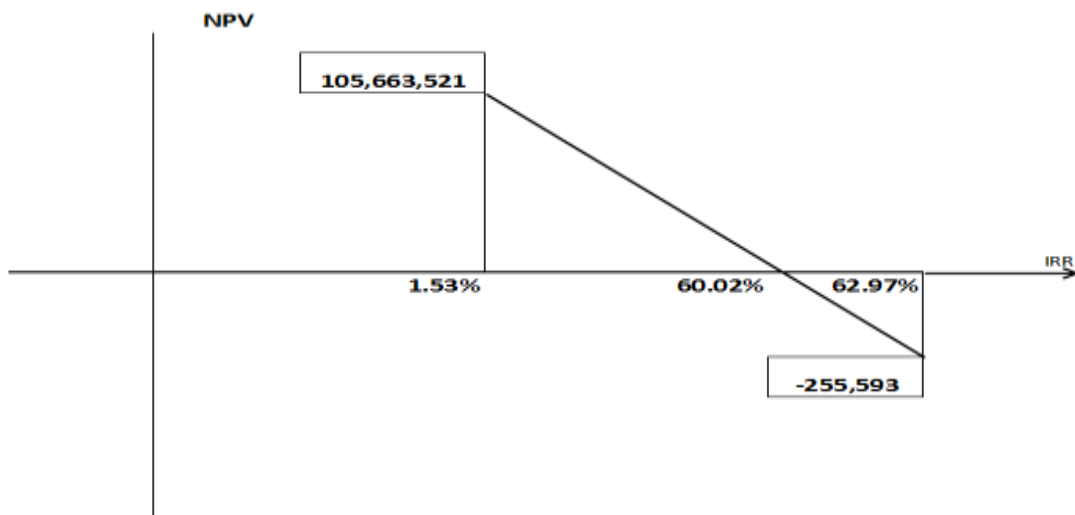
Table(12) :NPV of Cast in Situ

Month	Cash Flow	NPV
0	0	0
1	-873,180	-860,014
2	-1,231,160	-1,194,312
3	-4,665,186	-4,457,318
4	574,936	541,035
5	-19,810	-18,360
6	3,462,448	3,160,768
7	5,527,044	4,969,399
8	3,618,698	3,204,533
9	7,139,867	6,227,363
10	9,925,720	8,526,634
11	3,891,441	3,292,514
12	3,114,130	2,595,108
13	12,463,906	10,229,973
14	9,795,335	7,918,468
15	10,059,604	8,009,480
16	7,817,574	6,130,516
17	9,974,386	7,703,937
18	2,224,568	1,692,286
19	1,136,541	851,559
20	344,339	254,107
21	1,022,613	743,265
22	480,095	343,686
Net present value		69,864,629
		69,864,629
IRR		37%

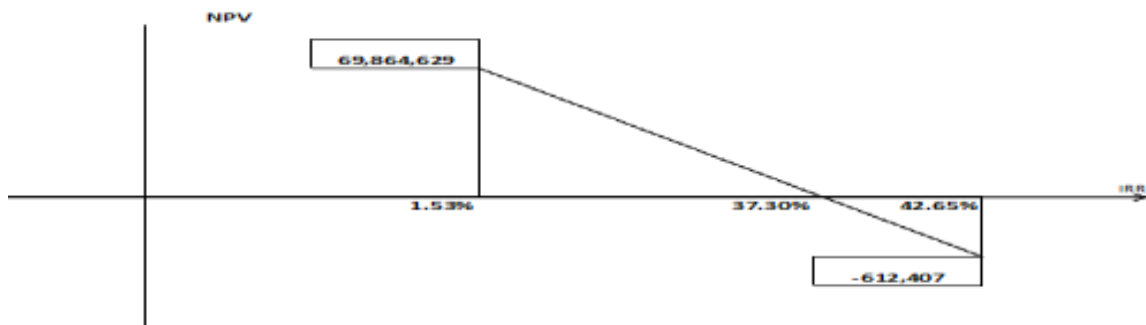
Interest: 20% monthly rate: 1.53%



Fig(7) :Graphically chart of Tilt-Up IRR



Fig(8) :Graphically chart of Pre-Cast IRR



Fig(9) :Graphically chart of Cast in situ IRR

All that percentage are very high but it is phase of construction not all stages so , if the view extend to the other stages to the end of project all that percentage decrease but the tilt -up still the best method because all other stages of finishing are the same cost and duration

But still the three methods of construction are still give good mark up, so the select between them will be on the best one

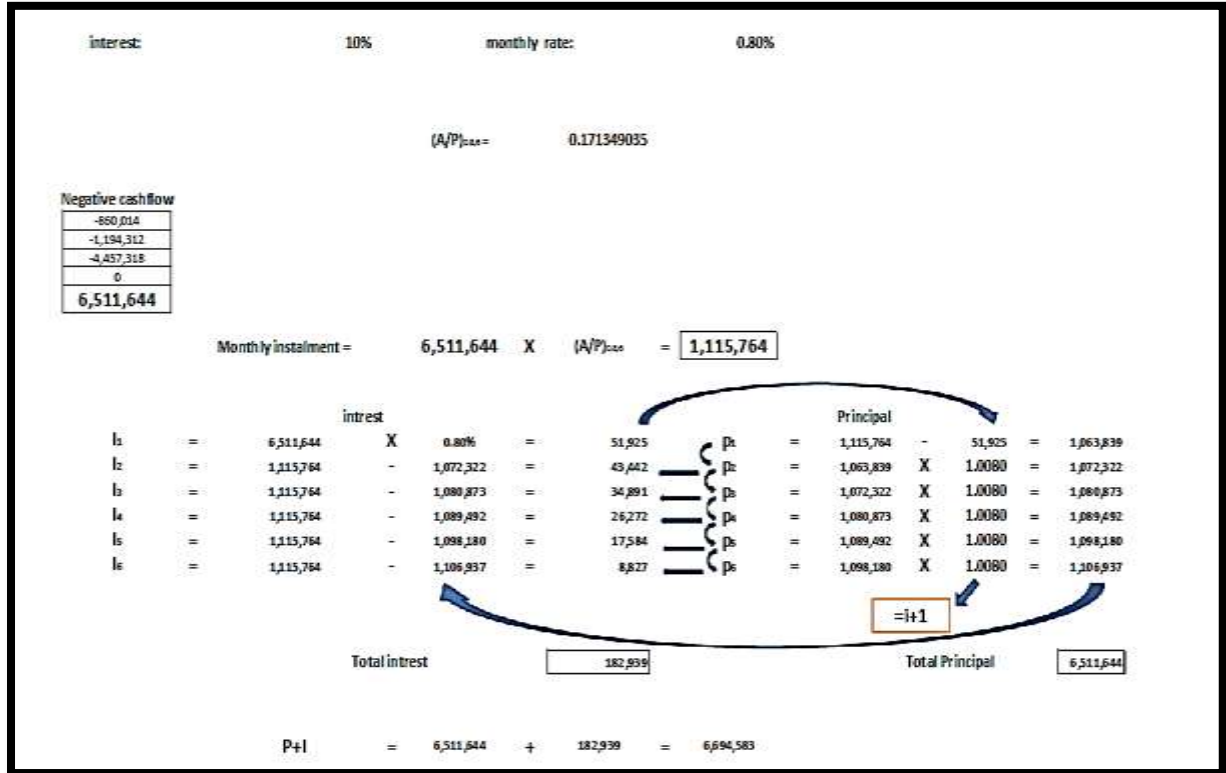
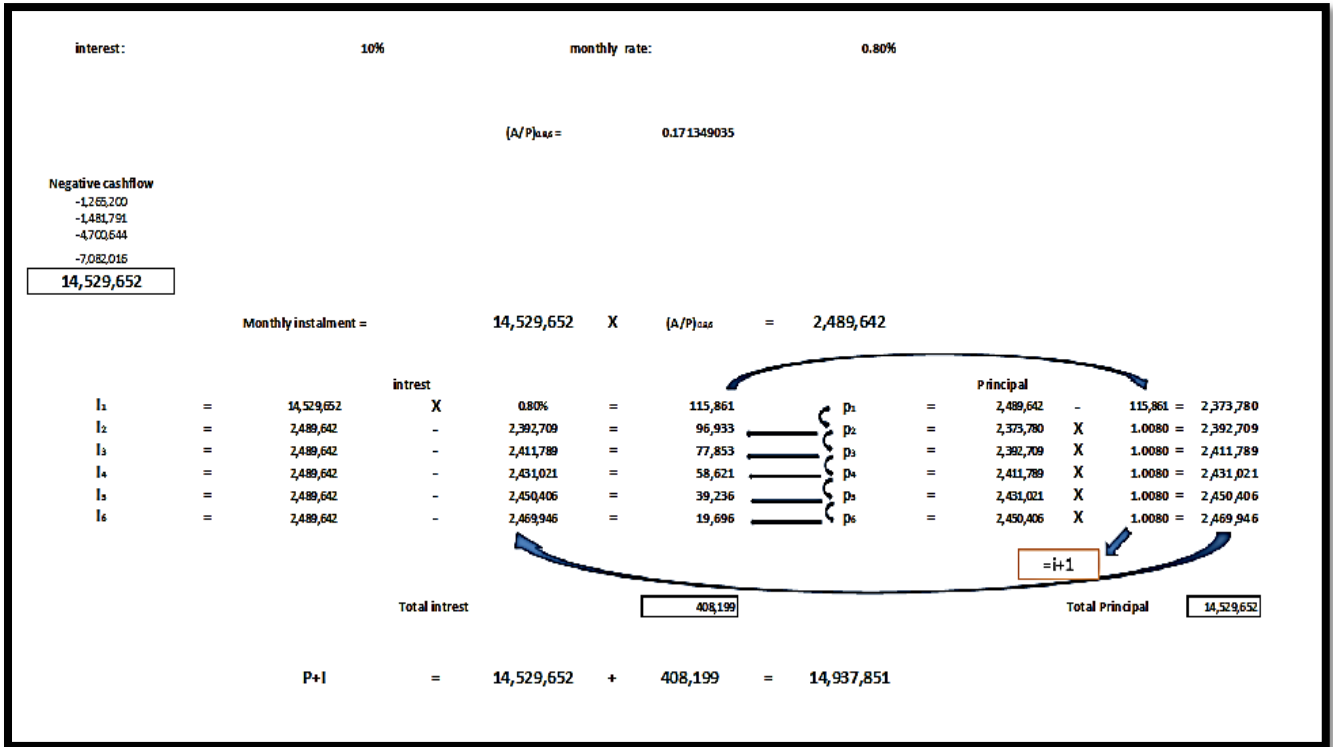
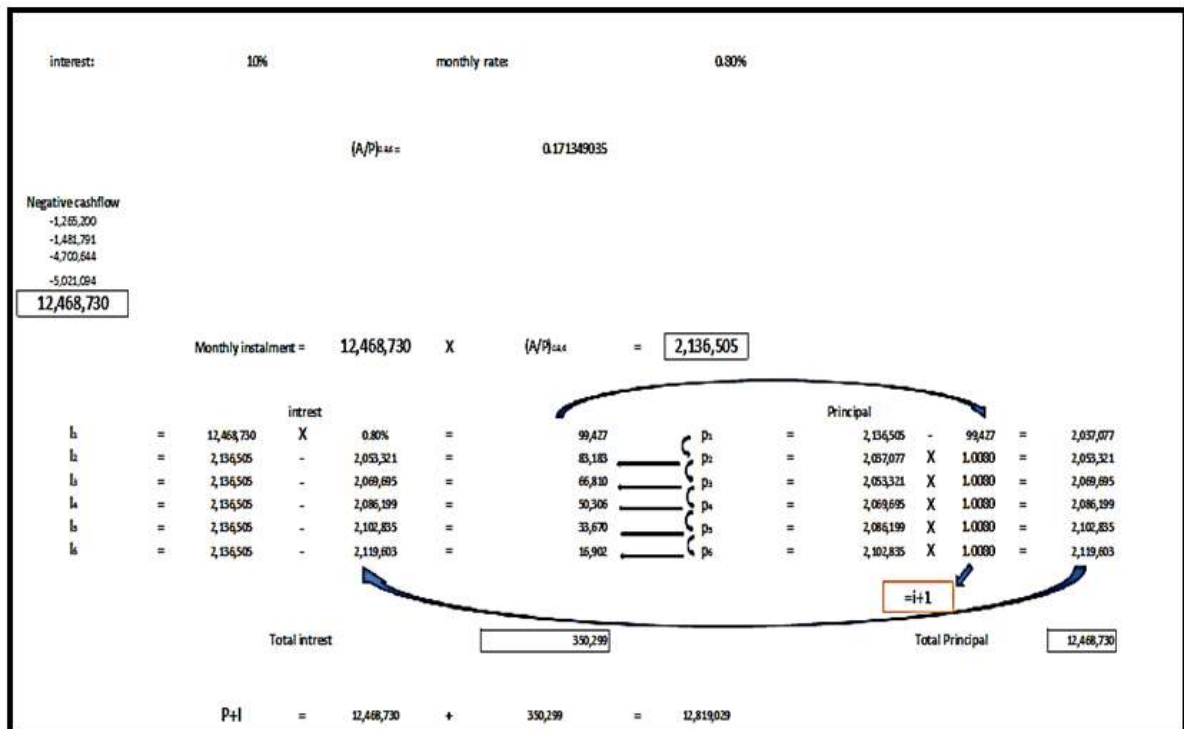


Fig (10):Cast In Situ Pay Back Period



Fig(11) :Pre-Cast Pay Back Period



Fig(12) :Tilt-Up Pay Back Period

For the first view the cast in situ is the best solution but for all the project age it isn't the best one because in the pre-cast ,need the highest fund but mark up is higher than cast in situ ,in tilt up system fund needed is less than in pre-cast and have higher mark up so it's the best solution for the site conditions.

4. Conclusion

Parameter of time is very important parameter in the construction field that open way to discover a new modern construction methods more than conventional one , a lot of methods have been created, prefabricated concrete like pre-cast and Tilt-up systems are one of this systems .

In horizontal extend , pre fabricated systems is more effective more than any other modern systems ,pre-cast and Tilt -up system both of system s are high in initial cost if the project is ordinary project with all resources are available and near even the time of project is sufficient to finish in schedule and mass of production or quantity of concrete need to be casted , to keep the economy of the project .

Tilt- up different than the pre-cast system, first in casting place in tilt up the concrete panel casting in site on slab floor or any prepared floor , in pre-cast cast in factory or patch planet may in factory can control the quality but in site can improve the quality as should as wanted ,pre cast need to transport the panels casted from the factory to the site That eliminate the size to transport because size of vehicles deck and traffic case in the way from factory to site location , erecting element in site the both of system are very near ,except the size of erecting in tilt-up can be al high of building but the precast is limited .

Tilt up need good planning to keep the project in sequence because any lag in sequence will increase the cost , due to the high cost of rent the cranes in erecting , and high number of labors in site ,pre-cast and tilt-up need more attention in finishing connection before release the temporary bracing ,and not release them until get permission of engineer to avoid any failure on panels .

5. Proposed Recommendations

Based on the above information, the following conclusions can be drawn:

- 1) Construction field need all new modern technique to save time and a lot of cases save money too.
- 2) Determine the suitable system of construction if it is traditional or modern , to keep the project economy .
- 3) Prefabricated system are suitable for horizontal extend like "residential cities , stores ,all cities less than six floors ".
- 4) In tilt-up system need more attention in planning sequence, avoiding any losses in time or money .
- 5) Tilt-up need more attention in "panelize" step and in panel design to decrease the capacity of cranes ,to decrease cost .
- 6) Determine the mass production , of the project to make tilt up system more effective .
- 7) Study erecting sequence ,keeping normal flow of work

Look wide range in cash flow of project ,and don't be fooled by the initial cost of the system and look for the benefit for the long term of cash flow .

References

- [1] **Tilt-Up Concrete Association(2011):** " THE CONSTRUCTION OF TILT-UP", Published by Tilt-Up Concrete Association.
- [2] **Tilt-Up Concrete Association(2006):** " Tilt-Up Construction And Engineering Manual", Published by Tilt-Up Concrete Association
- [3] **Smith, L. (2009):** "Tilt-up Engineering A-Z" , structure magazine.
- [4] **Remmetter ,m., Walters ,s. and Steubicker ,J.(2013):** "Multi- Story Tilt-up Building" ,structure magazine.
- [5] **Sullivan ,G. ,wicks ,E. , luxhoj , J.(2003)** : " ENGINEERING ECONOMY ", twelfth edition, Pearson Education ,Inc.
- [6] **Park, C (1997):** "Contemporary Engineering Economics", Addison Wesley Longman ,Inc.